ADAS HMI using peripheral vision

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ABSTRACT
We propose to enhance utility of Advance Driver Assistance Systems (ADAS) with an interface that creates luminous signals able to be handled by peripheral vision while driving. The system, called Lighting Peripheral Display (LPD), consists of a box illuminated by LEDs whose light is reflected onto the windscreen. The shapes of the box are designed so that reflections can easily match the problems signaled by the ADAS. Surface, colors and movements are modulated to graduate urgency and to discriminate between the different assistance systems.

A user test has been done on a driving simulator to compare a cluster with and without LPD. Both subjective and objective data (oculometry, vehicle parameters) were collected. They show that driving performance and comfort are enhanced by LPD. Reaction time is reduced for the most frequent warnings; perceived utility of ADAS is increased. However, driver's eyes tend to look at LPD instead of the cluster; peripheral vision utilization is thus not validated but, as ocular path is smaller with LPD, it helps the driver to keep his vision on the road.

General Terms
Design, Experimentation, Human Factors, Performance.

Keywords
ADAS, HMI, peripheral vision, user experience, driving simulator.

1. INTRODUCTION
To enhance security in cars, manufacturers are developing Advanced Driver Assistance Systems (ADAS) that help the driver to realize that he is taking some risk, for example being too close to the car in front of him. The system can either simply inform the driver or take some control of the car (in the previous example, the car can either report the short distance or reduce the speed). One key question is to provide an interface that would warn the driver in a way so that he would react properly. Any sign that would panic or distract him is to be avoided because security would thus be worse than without a system. When several ADAS are on board, another key feature of the interface is to clearly inform which system is doing the warning.

Different sensorial modalities can be used to design the interface. Usually, visual displays, like clusters on the dashboard, or head-up displays (HUD) are used, mixed with sounds. Auditory warnings are more appropriate than visual ones for urgent situations because they induce a quicker reaction (cf. Kohfeld [1]). Haptic can also be used, on the steering wheel or on the seat; some studies show that this modality is considered as more appropriate and less annoying than the auditory one (cf. Lee [2] for example).

HUDs are interesting to minimize the ocular distance between the display and the driving scene, but their price is not very cost effective because they require a windscreen modified to avoid double image.

We have developed a cheap display for ADAS that can be seen thanks to peripheral vision. We called it Lighting Peripheral Display (LPD). This modality has the advantage to allow the driver to keep his eyes on the road. We conducted a user experience on a driving simulator to compare LPD to a cluster, to check if driver reaction is shortened and driving comfort enhanced.

2. BIBLIOGRAPHY
2.1 Peripheral vision
Strasburger [3] refers to foveal vision below 2° eccentricity and to peripheral vision for anything outside 2°. The difference consists mainly in the form recognition performance: above 2°, visual acuity decreases dramatically (cf. Mandelbaum [4] quoted by Olson in [5]). According to Olson, peripheral vision ends up around 180° and narrows with age, ending up at 140° over 80 years. Claverie ([6]) defines the following areas within the binocular visual field of a standing human: up to 30° horizontally and 20° vertically, careful attention is possible ; up to 100° horizontally and 80° vertically, impression can be collected; up to 180° horizontally and 125° vertically only alerting movements are still detected.

Some colors support eccentricity better than others. According to Ayama [7], red, orange, yellow and blue induce a sensation that is constant up to 60°. Additionally Sakurai [8] showed that this result does not depend on surround luminance. Sensation induced by green turns to yellowish green from low eccentricities, whereas purple starts to be seen as bluish from 40°. Naili's work [9], dedicated to large eccentricities up to 80°, shows that color categorization performances are not modified for red and blue;

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precision is reduced for yellow and black from 60°, for green from 40°, and grey is affected below 20°.

According to Knau [10], stimulus size below 0.4° should be increased if one wants to keep visual acuity and perceived hue, when the stimulus is seen with peripheral vision (study made up to 6°).

Some movements are better detected in peripheral vision than others. Bartram [11] showed that linear movements are better detected at lower luminance levels than centered movements (that is movements where the center is unchanged like in blinking movements). This study also concludes that movements over several degrees tend to attract foveal vision.

2.2 Useful vision field

Here is a definition proposed by Rogé [12] who quotes Mackworth [13]: "the useful vision field corresponds to the surface around the point of fixation inside which information can be perceived and processed during a visual task". Driving is the task considered here. With age and vehicle speed, the size of the useful vision field is reduced according to a so-called "tunnel effect" (cf. Rogé [14] & [15]) : it drops from 14° for a 28 years old person to 11°for a 50 years old person.

2.3 Focal versus ambient vision and driving

According to Leibowitz's theory explained by Olson in [5], two independent modes are processing visual information. Focal mode is concerned with object discrimination and identification; it is optimal in the foveal area; it is largely affected by level of illumination. Ambient mode deals with spatial orientation; it is realized by both foveal and peripheral areas; it is less sensitive to illumination levels.

Horrey [16] adds that the focal vision is situated in the central 20-30° of the visual field and is upper field dominant, whereas the ambient vision, that goes up to 180°, is lower field dominant because of the importance of optic flow information in ground-based locomotion. According to Horrey's review, drivers are able to time-share focal and ambient task. Typically, lane keeping and speed control may utilize ambient vision, well-supported in the peripheral visual field. Focal vision is nevertheless required to identify hazards; in this case, peripheral vision function consists of detecting information relevant to attract foveal vision (cf. Lee [17]). Bouillot [18] shows that peripheral vision performances depend on mental load: when a task becomes more complex, attention focuses on foveal vision; crucial information can thus be missed by peripheral vision. Crundall [19] concludes similarly that an increase in foveal demand tends to decrease extra foveal attention, especially above 7° eccentricity, without any benefit from experience.

2.4 Head-up displays

According to Gish's review [20], HUDs have two major advantages: they increase eyes-on-the-road time and reduce accommodation demands to switch from display to external targets and reverse. This second advantage is especially interesting for older drivers (cf. [5]). Nevertheless, both visual and cognitive issues should be discussed. Information displayed on HUDs masks external objects via contrast interference, which is critical if HUD contrast is high, for example at nighttime. It also increases visual clutter, especially if the amount of information is large, and it distorts the driver's perception of external object distances (cf. Wickens [21]). External objects tend to be more difficult to detect (delayed responses, missing targets) if they are unexpected (cf. Fadden [22]) or not conspicuous (cf. [20]). This difficulty to switch from HUD to primary driving task is called "cognitive capture": when the driver is looking at HUD, his eyes are on the road indeed, ambient vision helps to control the vehicle but focal vision is not ready to efficiently detect hazards. Some studies, like Charissis [23], conclude that HUD is useful when visibility is low but increases distraction risk when visibility is good.

3. INTERFACE DESCRIPTION

3.1 Objectives

Our aim is to produce luminous signals that can be detected by peripheral vision. Their luminance should be high enough so that they could be visible even in critical situations (aged driver driving at high speed, by bright sunlight).

These signals are supposed to represent different informative ADAS: distance warning (DW), based on inter-vehicular time to prevent rear end collisions, lane departure warning (LDW), blind spot warning (BSW) and over speed (driving above speed limit). They should be recognized without the help of foveal vision. There should be enough differences between them to understand which system is alerting.

DW has two urgency levels: the lower, level 1, is reached when inter-vehicular time goes below 2s; the higher, level 2, corresponds to an inter-vehicular time smaller than 0,8s. Note that according to Lee [2], graded alert is better for rear end collision avoidance

Similarly to HUDs, LPD should increase eye-on-the road time compared to head-down displays. It requires no accommodation effort because its patterns are large and easy to identify. The amount of information is low, restricted to warning status, whereas HUDs typically also display speed values and guidance messages. Mask of external objects and visual clutter are thus negligible with LPD. Additionally decision making should be simple because signals will appear only when there is a problem to solve.

3.2 Conception

To help detection, one solution is to localize signals at small eccentricities: we create signals on the lower part of the windscreen. The upper part of the signal should stay below foveal vision. We thus decide to place the upper part below 3.5° for the 50th percentile male driver. The signals cover a surface of approximately 4° height and 9° width. It thus stays within the useful field of view while driving in any situation.

To help recognition, we use simple shapes that differ from color, position and type of movement. Each shape should be large enough: we decide that at least one dimension should be above 1°. Surface should nevertheless be graduated according to urgency scale: over speed gets thus a smaller surface than DW. Color is also chosen to match message urgency. White, amber and red are used; green is avoided considering its weak resistance to eccentricity. To allow drivers affected by dyschromatopsy to discriminate messages, color is always associated with either a difference in movement or location. Position is coherent with driver's view: a message that concerns a problem on the left (like LDW on the left hand side of the road) is located on the left hand side of the driver. Signals follow thus symmetry around the longitudinal axis that crosses driver's head. As summary, design principle is the following: the events on the road shown by LPD signals are positioned according to driver's point of view. Additionally, the least urgent message, over speed, is placed the farthest from the driver's line of sight.

The figure 1 below shows the luminous signals to create on the windscreen. The three arcs correspond to DW: either amber with a slow vertical movement, from the first arc on the bottom to the third on the top, at level 1, or red with a simultaneous quick blinking of the 3 arcs at level 2. Rhythm is accelerated to match increased urgency. The white semi-circle with a red ring is on, without blinking, during over speed. The dotted lines are used for LDW: blinking amber on the considered side, non-blinking grey on the other. The area between the dotted line and the semi-circle is on in amber when BSW is on, on the relevant side.

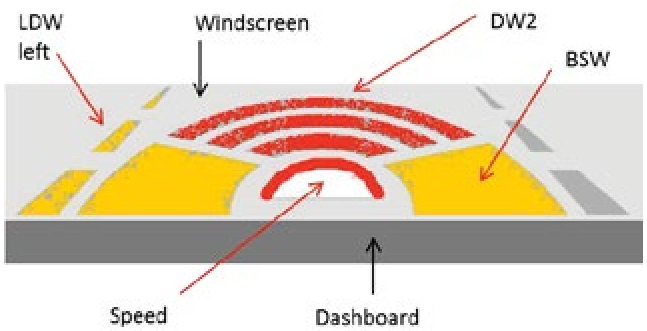

Figure 1. Luminous signals on the windscreen

3.3 Description

To create these signals, we use a box that is illuminated by LEDs placed on an electronic card that is connected to CAN bus. As soon as the card and the film are fixed on the box (see figure 2 below), we place a cover around and install it into the dashboard. This system is described in the patent 12-58619.

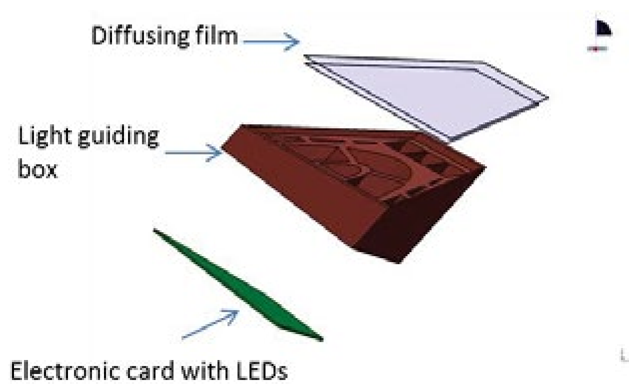

Figure 2. Lighting Peripheral Display content

LPD cost is around one-fourth of HUD price, even less. Needed volume in the dashboard is around 0,5l, far below the 5l usually required by HUDs.

3.4 Complementarity to cluster

One usual location for clusters is behind the steering wheel. In such a condition, LPD luminous signals are located on the ocular path followed by driver's eyes to look at the cluster. LPD and cluster are thus complementary, especially for over speed warning where LPD warns that a threshold is overrun and the cluster indicates the value of speed limit.

Whereas LPD signals are displayed only in warning status, cluster signals are always visible because they also present the operational status of the ADAS. To study the case of an inexpensive car, we choose to display ADAS through icons in the cluster. The following table 1 describes how the cluster indicates the operational and warning status of the different ADAS. Note that the sign used for BSW is taken from ISO 2575 ([24]).

ADAS	Operational	Warning
LDW (similar for left and right hand sides)		
DW		Amber at level 1 Red at level 2
BSW (here for left hand side)	Green	
Over speed	110	110

Table 1. Icons used on the cluster

As an example of display on the cluster, we show in figure 3 the case of over speed combined with BSW on the left hand side, whereas LDW and DW are operational.

Figure 3. Example of display on the cluster

4. USER EXPERIENCE TEST

4.1 Hypothesis

We would like to test the following hypothesis: (1) compared to a cluster placed behind the steering wheel, LPD reduces reaction time, (2) enables the driver to longer keep his foveal vision on the road, and (3) improves driving comfort.

4.2 Description

4.2.1 *Subjects*

26 persons (17 men and 9 women) participated in the test. They work within Renault but have no connection with HMI or ADAS studies. Their age varies from 24 to 50 (mean = 40).

4.2.2 *Driving situation*

We used the driving simulator Cards2 of Renault that consists of a car placed on a hexapod. Driving scene is displayed in front and on both sides of the driver. Rear and inside mirrors are represented by screens that display the appropriate rear scene. Following software is used to simulate driving: SCANeR, Labview and Visual Studio.

We chose a two-lane motorway with quite heavy traffic and some slow cars. As we instructed the subjects to drive as closely as possible to the speed limit, they had to overtake slower cars and tended to drive more on the left way than on the right one. Speed limit varies from 90 to 130 km/h, with some speed limit signs being skipped to create opportunities of over speed, which reproduces situations where the driver misses the sign. If the driver did not naturally create blind spot warnings, we had the possibility to let a quick motorbike overtake the driver, even on his right hand side.

4.2.3 *Collected data*

We measured different CAN bus values, especially accelerator pedal position and warning duration for each ADAS. We also measured driver's eye position with an EyeTechLab eye tracker placed on driver's head.

4.2.4 *Procedure*

In a first phase where ADAS were not operational, cluster hidden and LPD unlighted, each subject drove 10 minutes long on the simulator to get used to it.

Driving was then stopped and we presented each LPD signal and each cluster icon to the subject: we asked him to freely explain what he understood from the sign. We then gave him the expected meaning.

In a third phase, driving started again, with ADAS operational, cluster visible and either LPD switched off or on. This phase lasted 20 minutes. It ended up with questions about the tested configuration, "cluster" or "cluster + LPD". One of the questions concerned the perceived utility of each ADAS (the question was "in which measure has the ADAS helped you make a decision?"); the subject had to give a score along a 6 point scale: from 1 "not useful at all" to 6 "very useful".

The second configuration was then tested.

The last phase (20 minutes) dealt with questions, regarding either each warning or the overall impression with and without LPD, according to 6 point scales similar to the one presented above. The questions were the following: "have you appreciated the interface?", "have you found that the interface was useful for your driving (anticipation of problems)?", "do you think that the interface would help you to better focus your attention on the road?", "how about the comfort of the interface?".

Half of the subjects tested the configuration "cluster" first and "cluster+LPD" second, and half of the subjects reverse, to counterbalance the independent variable "configuration".

4.3 Results

4.3.1 *Hypothesis 1 and 2*

For each ADAS, we want to compare reaction times and ocular behavior with and without LPD. For DW, we will consider separately the three different cases: in level 1, the warning is on at level 1 and turns off; in level 2, the warning is on at level 2 and turns off back to no warning; in level 2-1, the warning is on at level 2, goes down from 2 to 1 and turns off.

Reaction time for over speed and DW corresponds to the duration between the beginning of the warning and the moment when accelerator pedal position moves up, meaning that the driver starts to decelerate. For LDW, as steering wheel movement analysis is not a clear way to describe how the driver manages lateral control, we prefer to look at warning duration: when the warning stops, this means that the driver is back into his lane. For LDW, reaction time is thus equal to warning duration. For BSW, we consider that reaction time is equal to the duration between the beginning of the warning and the moment when the driver's eyes arrive into one of the mirrors.

As driving performance can first be described by the number of warnings that induce reaction or not, we present these results in the following table 2. It contains the sum of signals over all subjects for each configuration, "cluster" and "cluster+LPD", and for each warning.

Warning	Nb of signals inducing a reaction		Nb signals not inducing a reaction		Total
	Cluster	Cluster+LPD	Cluster	Cluster+LPD	
Over speed	182	158	30	17	387
DW level 1	95	97	68	64	324
DW level 2	57	37	41	26	161
DW level 2-1	58	63	22	17	160
BSW	55	102	0	2	159
LDW	75	79	1	2	157

Table 2. Number of signals inducing reaction or not

One can see that over speed and DW are the warnings that are the most often released. We do not have any explanation about the higher number of BSW in "cluster + LPD" configuration. One interesting result is the lower number of DW level 2 with LPD, and the lower number of over speed warnings inducing no reaction with LPD. Otherwise, results are similar with or without LPD.

For cases inducing a reaction from the driver, we analyzed reaction times. For each warning, we did an ANOVA to check if differences were significant (if p >5%) or not (NS). The independent variable was the configuration, "cluster" versus "cluster+LPD", and the dependent variable was the reaction time, as defined above. The following table 3 contains, for each warning, the mean values of both configurations and the p-values.

Warning	Cluster Reaction time (s)	Cluster+LPD Reaction time (s)	Difference
Over speed	1,36	0,84	p<0,001
DW level 1	1,36	0,78	p<0,005
DW level 2	0,79	0,65	NS(p=0,4)
DW level 2-1	1,82	1,24	NS(p=0,07)
BSW	2,27	1,04	NS(p=0,2)
LDW	0,87	0,87	NS(p=0,9)

Table 3. Reaction time

Reaction is significantly quicker with LPD for over speed warning and DW at level 1. For DW level 2-1, the difference is not significant but p-value is close to 5%. For DW level 2, BSW and LDW, there is no difference.

Thanks to oculometry, we could measure the time spent by foveal vision on the following areas of interests: road, cluster, LPD, mirrors and "other areas". These gaze durations were collected within each sequence of interest, that is within each warning duration. We summed the duration on each area of interest over all the subjects, for each configuration and each warning, and calculated from this the percentage of time spent on each area. We focus here on the three main areas, presented in the table 4 below: road, cluster and LPD (valid only for "cluster+LPD" configuration). As the subjects did not look very often at the mirrors, except during BSW, we do not present these areas. We add a column to show the sum of percentages on cluster and LPD for the "cluster+LPD" configuration, to compare it to the percentage on the cluster in the "cluster" configuration.

Warning	% road		% cluster		% LPD	% cluster +LPD
	Cluster	Cluster +LPD	Cluster	Cluster +LPD	Cluster+LPD	
Over speed	80	75	12	10	7	17
DW level 1	73	73	14	8	9	17
DW level 2	70	80	16	3	2	5
DW level 2-1	72	77	17	5	8	13
BSW	52	62	8	2	7	9
LDW	75	80	16	4	10	14

Table 4. Percentage of gaze duration

Percentages on the road are similar with and without LPD, except for BSW: in this case the driver looks more at the road with LPD than without. Percentages on the cluster are reduced with LPD, except for over speed. In this case, the driver probably needs to look at the cluster to know to which limit he should reduce his speed. Percentage on LPD signals is almost equal to the reduction observed on the cluster, which means that the driver looks at LPD signals instead of looking at the cluster.

Oculometry gave us also duration of gazes and number of glances on the different areas of interest. Duration is interesting to look at for cluster and LPD. Duration on the road is not a good indicator because it is biased by the total warning duration. Number of glances on the road is instead a good indicator.

The following table 5 concerns duration of gazes on the cluster and on LPD. It contains mean values, standard deviations (SD), and p-values given by the ANOVA where the independent variable is the configuration, "cluster" versus "cluster+LPD", and the dependent variable is the duration of gaze on the cluster.

Warning	Gaze duration on the cluster (s)					Gaze duration on LPD (s)	
	Cluster Mean	SD	Cluster+LPD Mean	SD	difference	Mean	SD
Over speed	1,18	1,5	0,48	0,70	p<0,001	0,35	0,54
DW level 1	0,90	1,46	0,25	0,55	p=0,03	0,29	0,38
DW level 2	0,70	1,17	0,11	0,20	p=0,025	0,09	0,27
DW level 2-1	1,45	1,95	0,28	0,67	p<0,001	0,49	0,79
BSW	0,19	0,38	0,03	0,09	p<0,05	0,11	0,20
LDW	0,20	0,32	0,03	0,11	p=0,001	0,09	0,15

Table 5. Gaze duration

Gazes on the cluster are always longer without LPD, and meet a quite high value (1,45s) during DW level 2-1: 1,45s is above the limit of 1,2s proposed by Zwahlen (cf. [25]) to check if a visual information is safely displayed or not. Thanks to LPD, gaze on the cluster never exceeds 0,5s. It sometimes gets very low values (0,03s) that are due to averaging: some drivers do not look at all to the cluster, some do.

Gazes on LPD never exceed 0,5s. This value is obtained for DW level 2-1 that is the warning which lasts the most, as shown in table 3. The lowest values (0,09s) are a due to averaging.

We analyzed number of glances on the cluster and on the road. We did an ANOVA to check if differences were significant. The independent variable was the configuration, "cluster" versus "cluster+LPD", and the dependent variable was the number of glances. The following table 6 concerns the number of glances on the cluster. It contains, for each warning, the mean values of both configurations and the p-values.

Warning	Cluster Nb of glances on the cluster	Cluster+LPD Nb of glances on the cluster	Difference
Over speed	2,9	1,4	p<0,001
DW level 1	2,1	0,5	p<0,001
DW level 2	1,9	0,4	p<0,05
DW level 2-1	1,5	0,3	p<0,001
BSW	0,2	0,03	p<0,05
LDW	0,7	0,03	p<0,05

Table 6. Number of glances on the cluster

In coherence with gaze duration, this number is always lower with LPD than without. During over speed, even with LPD, the driver looks at the cluster at least once, probably to compare his current speed to speed limit.

The following table 7 concerns the number of glances on the road. It contains, for each warning, the mean values of both configurations and the p-values.

Warning	Cluster Nb of glances on the road	Cluster+LPD Nb of glances on the road	Difference
Over speed	4,1	3,3	NS(p=0,09)
DW level 1	3,7	2,4	P=0,02
DW level 2	3,0	2,2	NS(p=0,2)
DW level 2-1	4,20	4,23	NS(p=0,96)
BSW	1,9	1,4	NS(p=0,06)
LDW	1,15	1,29	NS(p=0,27)

Table 7. Number of glances on the road

There is no difference between both configurations, except for DW level 1 where the subjects significantly do less eye movements from the road with LPD than without. The over speed warning and DW level 2-1 are the ones with the largest amount of movement back and forth. During over speed warning, one has seen from the number of glances toward the cluster (cf. table 6) that drivers need to check the cluster several times. The explanation for DW level 2-1 is probably the length of this particular warning (cf. table 3).

4.3.2 Hypothesis 3

The comprehension question asked before driving with ADAS (phase 2 of the test) is interesting to look at to see which icons on the cluster and which signals on LPD are easy to understand or not. The following figure 4 reports the percentage of subjects whose comprehension from the signal meets the expected meaning. We did not test the comprehension of the speed limit sign used as an icon on the cluster for over speed because it would have obviously met a 100% comprehension score.

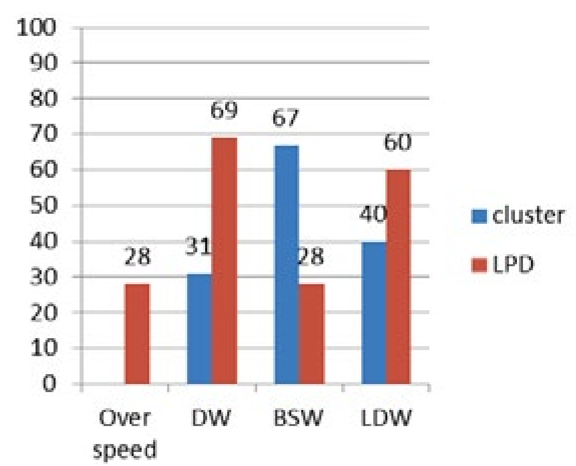

Figure 4. Comprehension score (%) of signals

LPD signal for over speed and BSW are not well understood; LDW and DW are easily recognized on LPD, but not on the cluster. BSW ISO icon is well understood.

After driving with one configuration (phase 3 of the test), driver's impression about the utility of each ADAS is the following:

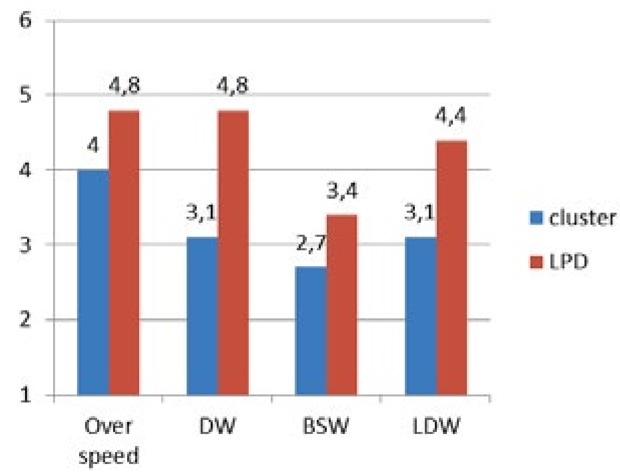

Figure 5. Utility score after testing one configuration

For each ADAS, utility is higher with LPD. DW is the system where LPD adds the most. BSW stays below score 4 ("a little bit useful").

After testing both configurations, the overall impression of the driver about either the cluster or LPD is the following:

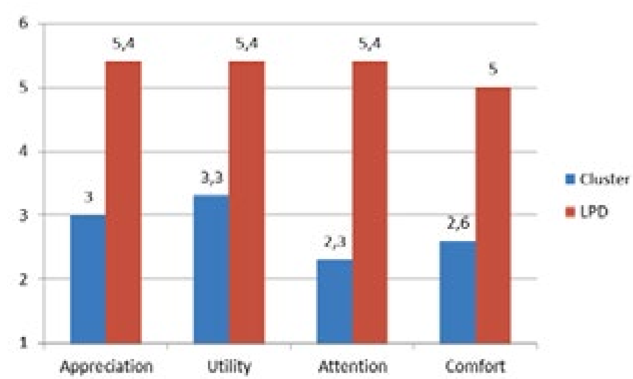

Figure 6. Overall impression after testing both configurations

LPD gets better scores than the cluster for all criteria. LPD is appreciated, seen as useful and comfortable, and helps to better focus one's attention on the road.

4.4 Discussion

Our first hypothesis that assumed that LPD would reduce reaction time is validated. Some ADAS, especially the one whose reaction to consists of reducing acceleration (over speed and DW), take a larger benefit from LPD than others (LDW and BSW). As over speed and DW are the ADAS that are the most often released during our test, one can conclude that ADAS with a LPD interface should help the driver to better adapt to the driving situation than a cluster located behind the wheel and displaying icons.

Our hypothesis that assumed that the driver could better keep his foveal vision on the road with LPD is not validated, except for BSW. Eye tracking analysis shows that the driver does not need to look at the cluster as often and as long as without LPD, but he instead looks at LPD signals to get information about the problem to face. LPD signals are thus not so well used through peripheral vision as we expected. This result can be explained by one of the functions of peripheral vision for driving listed by Lee ([17]):

peripheral vision has to guide foveal vision to interesting events. A longer habituation than 20 minutes is probably necessary to behave against this function.

One nevertheless can see a benefit to LPD because the length of the ocular path from the road to LPD is smaller than the one to the cluster. Even if focal vision is on LPD, ambient visual field is located on the road and should be able to control the vehicle. Visual distraction is thus reduced, which can have an effect on security especially for DW which can induce glances above Zwahlen's threshold.

Our hypothesis about driving comfort enhancement thanks to LPD is validated. Drivers appreciate this interface and estimate that it adds utility to ADAS. The design of some signals should be modified on LPD so that it could be easier to understand them, BSW and over speed warning especially.

5. CONCLUSION

Our study confirms that luminous signals dedicated to peripheral vision can efficiently interface ADAS: driving performances are enhanced, drivers claim more comfort with such an interface. These luminous signals can be created by a simple system, cheaper than HUDs. Compared to HUDs, some drivers appreciate that LPD creates a signal only when a problem occurs ("if I see nothing, this means that everything is OK"), and that it chooses to give a tendency instead of a value to analyze.

Some design principles should be followed. The first one is to find a way to spatially indicate a warning that corresponds with the localization of the real-world problem. Some people said that they thus have the impression of being protected by a radar that scans around for them. The second principle is to graduate surfaces, movements and colors according to urgency scale. The modulations would also help to differentiate the ADAS.

From our 20 minute test we concluded that drivers did not use only peripheral vision to react to warnings, but glanced instead at LPD signals. One should perform a longitudinal study on real cars to check if eyes stop to look at LPD after a while. The peripheral vision would thus be an interesting modality to use to design car interfaces because it would fill a gap between foveal vision and audition: auditory signals are hard to miss but often perceived as difficult to understand and uncomfortable, whereas signals dedicated to foveal vision can either be missed or be sources of visual distraction. Peripheral vision should have the potential to create an intermediate level to better interface ADAS and keep driver's eyes on the road.

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